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TREATMENT OF MARIGOLD FLOWER EFFLUENT IN KAASHYAP ENVERGY REACTOR

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ABSTRACT: India is predominantly an agrarian country and farmers explore commercial crops which can give them better returns. Cultivation of Marigold flowers is one such example. The process of extraction of Lutein from Marigold flowers generates difficult effluent with very high organic pollution load and there is no proven and established treatment method to meet the wastewater discharge norms as stipulated by the government pollution control boards. This study focusses on implementation of hybrid anaerobic reactor to treat the marigold effluent to reduce the organic load. The plant was designed to treat 120cu.m/d of effluent with organic loading rate of 6.9kgCOD/cu.m and HRT of 8 days. This paper shows long-term performance of the system over all the months in a season. The system showed a steady performance of 70-80% treatment efficiency for COD for whole season. The design basis and operational features are described. Statistical analysis was carried out for the data.

KEYWORDS: Anaerobic digestion; Marigold wastewater; Wastewater treatment; Lutein extraction.

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1. INTRODUCTION

India is predominantly an agrarian country and farmers explore commercial crops which can give them better returns. Cultivation of Marigold flowers is one such example. The process of extraction of Lutein from Marigold flowers generates difficult effluent with very high organic pollution load and there is no proven and established treatment method to meet the wastewater discharge norms as stipulated by the government pollution control boards (1). Marigold flower is a rich source of a Xanthophylls called Lutein which shows anti-oxidant and anti-cancer properties. This has led to various extraction and purification studies to obtain the high purity Lutein suitable for human applications (2). Agro-based industries opt for biological treatment processes for wastewater treatment, due to their high organic loads in wastewater. Biological treatment processes include anaerobic process followed by aerobic treatment processes. Anaerobic treatment being eco-friendly, is used in most of the agro based industries for removal of organic pollutants in wastewater. The anaerobic treatment besides having lesser energy consumption, produces energy in the form of methane (3,4).

1.1. Anaerobic digestion

Anaerobic digestion is a process, where the organic matter is digested by anaerobic organisms, which produce Biogas after digestion. Factors affecting the anaerobic digestion process include temperature, pH, nutrients, organic loading rate. The design parameters of anaerobic reactor depends on the type of the reactor selected. Anaerobic process is highly pH dependent. Optimal pH range for anaerobic process is found to be 6.8-7.2. The methanogenic bacteria require some nutrients and trace metals like nitrogen, phosphorous, sulphur, zinc, manganese etc (5–8).

1.2. Types of anaerobic reactors

There are various types of anaerobic digestion processes. Up-flow anaerobic Sludge Blanket (UASB) being the basic version of anaerobic reactors. This process is extensively used for municipal wastewater. The biomass is retained in the form of sludge granules at the top of the reactor forming a sludge blanket. These UASB reactors, however, have certain disadvantages such as long start up time, requirement of skilled staff for operation, non-resistant for shock loading etc (8,9). These limitations gave rise to invention of high rate digestion process which include fixed film reactors where bacteria is immobilized on biofilms (8), continuous stirred tank reactors (CSTR) which contain central and lateral agitators for proper mixing of effluent with sludge (10,11), anaerobic moving bed biofilm reactors (12–14), anaerobic baffle reactors (15–20), Anaerobic membrane bioreactors (21–24). However fixed film reactors, CSTR have certain limitations like channeling effects, maintenance problems and clogging problems (8). Membrane processes are high energy intensive processes. There is a need for new technological improvements in the anaerobic process as a primary treatment with enhanced removal efficiencies and lesser limitations. Secondary treatment is required for further removal of organic pollutants like chemical oxygen demand (COD) and biological oxygen demand (BOD) after anaerobic process which can be aerobic systems. The conventional process of obtaining activated sludge consists of passing wastewater through an aeration tank, a secondary clarifier and a sludge recycling line. High rate activated sludge processes are also tried in the industries with few limitations (25,26). Performance evaluation of existing wastewater treatment plants have been evaluated with aerobic treatment process which led to only 49% removal of COD from milk industry and 80% in textile industry when aerobic process is enhanced with lot of chemical additions in textile industry (27–29). This study focusses on implementation of hybrid anaerobic reactor (Kaashyap Envergy Reactor) to treat the marigold effluent to reduce the organic load. The plant was designed to treat 120cu.m/d of effluent. This study focusses on the performance evaluation of the full scale plant for one season. The system showed a steady performance of 70-80% treatment efficiency for COD for all the months in that season. The design basis and operational features are described. Statistical analysis was carried out for the data.

2. MATERIALS AND METHODS

2.1. Process flow description

The process flow diagram is presented in Fig. 1. The plant is designed to handle 120KLD of marigold processing wastewater, having about 50,000mg/l COD with a hydraulic retention time of 8 days and maximum organic load of COD 6.9kg/cu.m/day. The marigold processing wastewater is received in to a grit chamber with Bar screens to remove the grit followed by Oil & Grease Trap to remove floating oil. It is then pumped into a circular clarifier for removal of flower petals. The wastewater is then sent into equalization tank and neutralized to pH-6.5-7 for making the effluent suitable for anaerobic digestion. The effluent is pumped into hybrid type Kaashyap Envergy reactor. Overflow from the reactor is allowed to pass on to Primary Lamella Clarifier after small quantities of dissolved gases from the overflowing liquid are expelled in Degassing tower to facilitate better settling in Primary Lamella Clarifier. The settled solids which mostly contain active microorganisms which have escaped earlier from the reactor through overflow are recycled back into Reactor thereby maintaining adequate populations of active microorganisms in Kaashyap Envergy Reactor. Contents of the Kaashyap Envergy Reactor are adequately mixed and kept under proper suspension for optimum contact of microorganisms and organic content in the wastewater to facilitate high rate digestion using a Central agitator installed at the top of the Kaashyap Envergy Reactor and a recirculation grid placed in the bottom zone of the reactor. The treated effluent from Kaashyap Envergy Reactor is then passed onto a Diffused aeration tank for aerobic treatment. Effluent from aerobic treatment unit is sent into tertiary treatment system to further polish the wastewater to meet the norms of pollution control board for discharge. Excess solids from Lamella Clarifiers are taken to sludge drying beds.

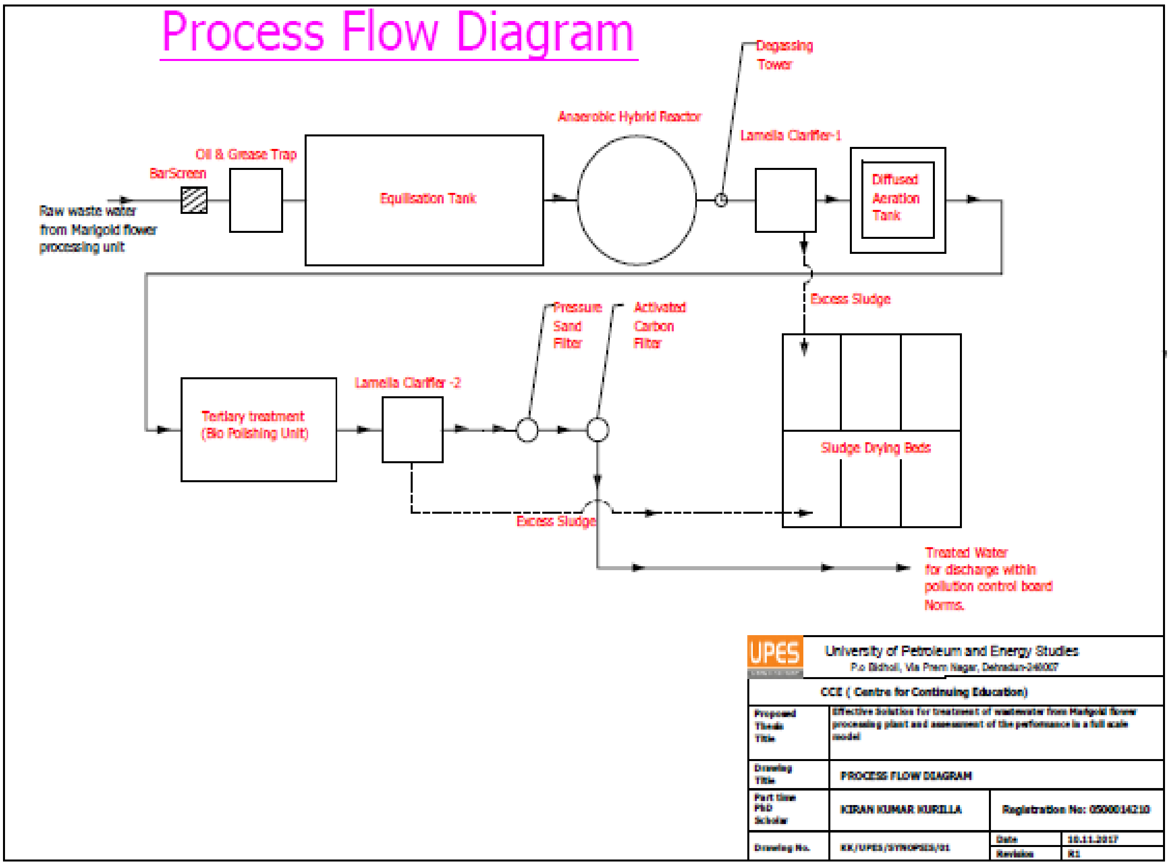

Figure 1: Process Flow diagram

2.2. Experimental

Characterization of the raw waste water is presented in Table-1. The following samples, such as (1) Raw wastewater (2) Anaerobic digestion outlet (3) Aeration tank outlet (4) Tertiary treatment outlet were collected once in a shift (8 h) and analyzed for pH, alkalinity, VFA, COD and TSS following Standard Methods for the Examination of Water and Wastewater (30). However, this study discusses Chemical oxygen demand (COD) and Total suspended solids (TSS) removal. Performance analysis was carried out along with statistical analysis.

Table 1: Characterization of raw wastewater

SN	Parameter	Unit	Quantity	Standard Deviation
1	Nature of effluent		Organic	
2	Odour		Floral	
3	Colour		Dark Brown	
4	pH		4.0	0.35
5	Total Suspended Solids	ppm	2500	353
6	Total Dissolved Solids	ppm	22000	5656
7	COD	ppm	45000	7071
8	BOD	ppm	23000	2828

2.3 Design and configuration of hybrid anaerobic reactor (kaashyap envergy reactor)

The Hybrid anaerobic reactor (Kaashyap Envergy Reactor) as seen in Fig-2 with a total active capacity of 960cu.m was operated in a continuous flow mode. The reactor contains a central agitator mounted on the top of the reactor. The Central agitator consists of shaft made of EN8 material of length 5500mm and a 3 bladed impeller of SS 316 material and of diameter 850mm. The Central Agitator is designed to rotate continuously at 71rpm thereby pushing the incoming wastewater from equalization tank to the bottom of the reactor through a Central chute of dia 1000mm.The wastewater pushed down by the central agitator hits the bottom of the reactor and comes out of the central chute through bottom openings and thereafter inside the reactor raises back to top level and it is in turn drawn back into the Central chute from openings made on the central chute above impeller level. A continuous movement of reactor contents within it is thereby established by the action of the Central agitator powered by a 11kw motor. In addition to these 3 numbers of Sludge recirculation pumps are installed at the bottom of the reactor equidistant along the perimeter at 120 Deg connected to a recirculation grid placed inside the reactor bottom surface. These pumps recirculate the microorganisms getting accumulated at the bottom of the reactor to the top and join the raw wastewater entering the reactor and get mixed with it due to the influence of Central agitator. This arrangement facilitates the availability of anaerobic microorganisms throughout the reactor.

Effluent feed to the reactor is kept constant at 6.5-7.5. The temperature was maintained at the level of 35 ± 1 C. $NaHCO_3$ was added to the feed solution to maintain pH at 6.5– 7.5 in the influent and hence to keep a pH level of 7.0 in the reactor. The hydraulic retention time (HRT) was 8 h. COD Nitrogen: Phosphorus ratio in the influent was maintained at an average of 250:5:1 by adding synthetic fertilizer in order to supply the microorganisms with adequate nitrogen and phosphorus.

Figure 2: Hybrid anaerobic reactor (Kaashyap Envergy Reactor)

3. RESULTS AND DISCUSSION

Marigold flower processing plant operates seasonally from July to December every year. The treatment plant for marigold processing wastewater was started with initial seed sludge. The reactor started with 40KLD effluent in batch process scaled to 120KLD continuous feed within a span of 30 days. Full scale operation of the plant was started during August of season-1.

3.1. Performance analysis

Monthly average pH and suspended solids values of (1) Raw wastewater (2) Anaerobic digestion outlet (3) Aeration tank outlet (4) Tertiary treatment outlet in season-1 are presented in Fig-3&4. Low pH is characteristic of marigold processing wastewater. Raw wastewater contains high suspended load along with flower petals. Grit chamber is provided for removal of bigger particles through screens. Circular clarifier is provided later to that to remove the flower petals. pH is increased to neutral in equalization tank for making the effluent suitable for anaerobic digestion. Fig-3 depicts the pH variation throughout all the months. pH was found to be in the range of 4-5 in the raw wastewater. pH is an important influencing factor for anaerobic digestion process. Methanogenic activity proceeds at a pH range of 6.8-7.3. pH more than 8, inhibits the methanogenic activity in the system and gives rise to sulphate reducing bacteria (5). pH at the inlet of anaerobic digestion was maintained in the proper range throughout all months. Anaerobic digester outlet, after lamella clarifier pH was around 7-7.5. However pH increased after aerobic treatment process falling in the range of pH 8-8.5. Final outlet pH, after tertiary treatment of the plant for all months was found to be between pH 7-8.5, which is under the limit.

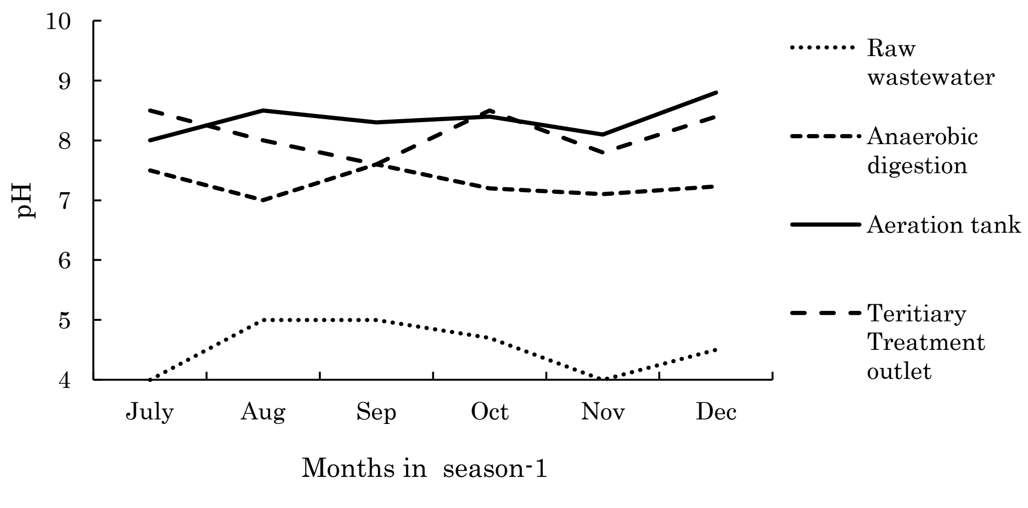

Figure 3: Monthly average pH

Fig-4 depicts the monthly average total suspended solids at each stage of the treatment system. Total suspended solids (TSS) in raw wastewater was found to be in the range of 6800ppm to 9100ppm. Anaerobic digester is fed with nutrients and sludge which increased the TSS values in the digester to 10,500ppm to 13000ppm.Lamellaclarifieroutlet after anaerobic digestion gave the outlet range as

5000-8500ppm. Aerobic treatment process along with lamella clarifier reduced the TSS values in the range of 1200-2500ppm for all months. Final TSS at the outlet of Tertiary treatment system was found to be from 190-300ppm. However October month has shown lower TSS values of raw waste water. This might be due to operational or environmental variations.

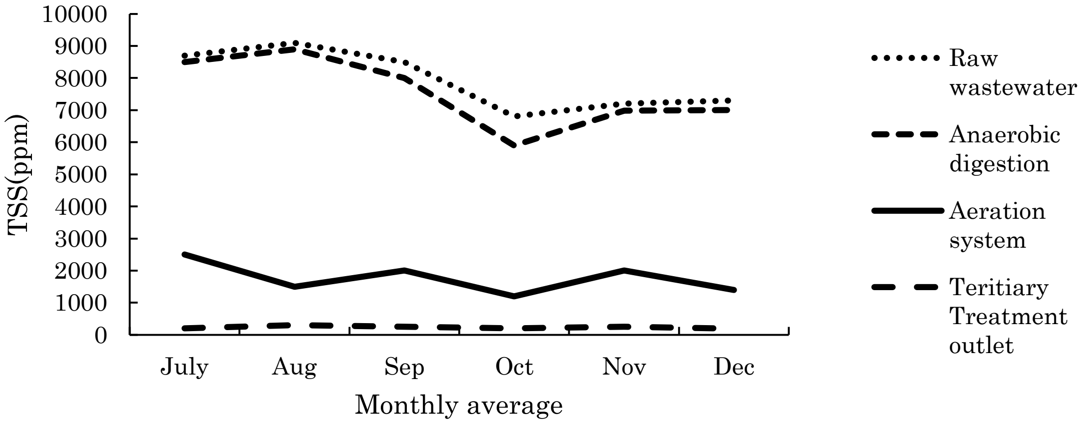

Figure 4: Monthly average TSS

Performance of the treatment plant was measured mainly by Chemical oxygen demand (COD) analysis. Organic content in wastewater is measured by COD. Monthly average COD values for all months from July to December have been recorded on daily basis for raw waste water, anaerobic digestion outlet, aerobic treatment outlet and tertiary treatment outlet (final outlet). Fig-5 represents COD values at all stages for all months in season-1. The average COD values for raw waste water for all months range between 35000 - 47500ppm. Anaerobic digestion process reduced the COD values of all the months in the range of 8000-14000ppm. Aerobic treatment process yielded a COD range of 1900-2500ppm.Teritairy treatment system resulted in final COD range of 150-250ppm which is the acceptable range as per the discharge norms of CPCB (31).

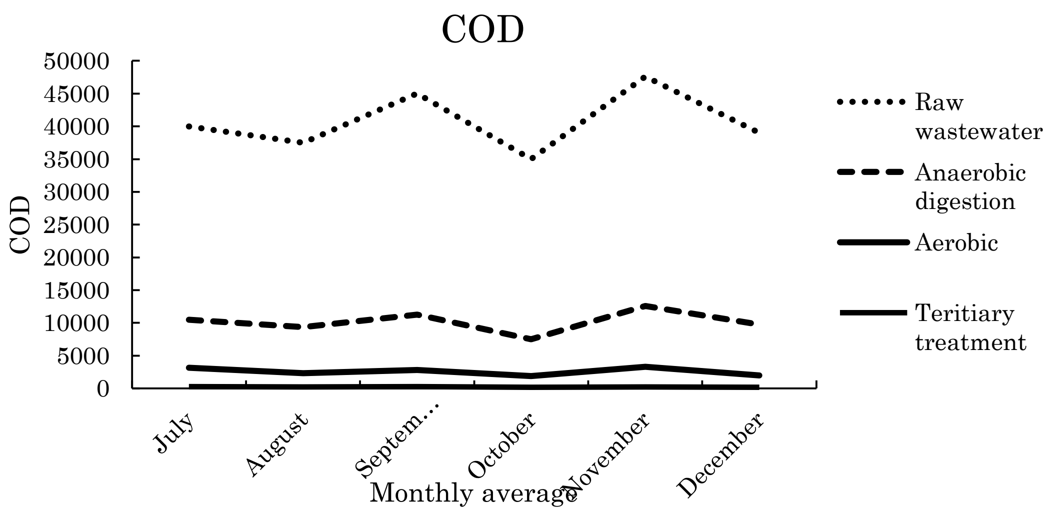

Figure 5: Stage wise COD analysis

3.2.Performance of Hybrid Anaerobic reactor

The performance of the Kaashyap Envergy Reactor was analyzed for all the months. Increase in pH value and reduction of volatile fatty acids and COD is an indication of conversion of organic compounds into methane and carbon dioxide in the reactor. The reactor performance is measured based on volatile fatty acids (VFA)/ alkalinity ratio. VFA/alkalinity ratio between 0.25 and 0.3 indicates good performance in the reactor (32). Monthly average of VFA and alkalinity ratio is indicated in Fig-6. Fig-6 depicts VFA/Alkalinity ratio of all the months are in the range of 0.25-0.3, indicating good performance of the reactor. The average monthly percent reduction in COD in anaerobic digestion is represented in Fig-7. The maximum value of COD reduction was recorded in the month of October where feed wastewater COD value is lesser.

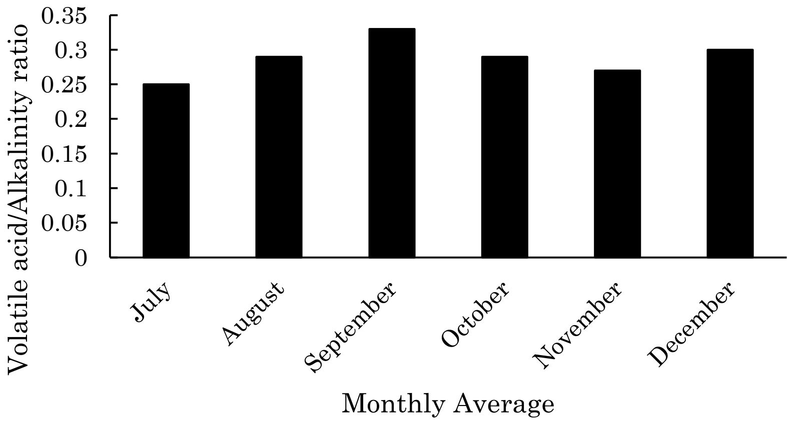

Figure 6: VFA/A ratio

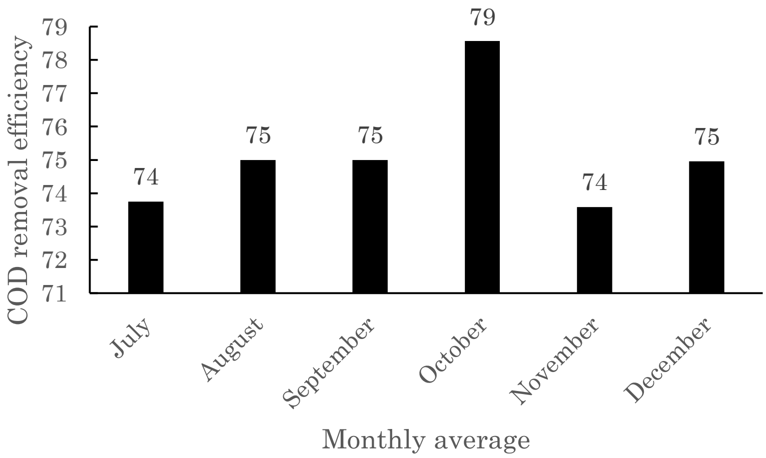

Figure 7: Percent COD reduction

3.3. Statistical analysis

Descriptive statistical analysis and regression analysis were carried out for COD removal efficiencies for all the months in season-1 using monthly average data. Statistical analysis have been carried out using the software 'Minitab-version-17'. Box plots have been plotted for stage wise removal efficiencies of COD. Medians of COD removal efficiencies at each stage of the treatment for each month are obtained. Fig-8 represents the box plot of the data. Raw waste COD median was found to be 39500ppm. Medians after anaerobic digestion, aerobic and tertiary treatment systems were found to be 10,133ppm, 2517 ppm and 237ppm.

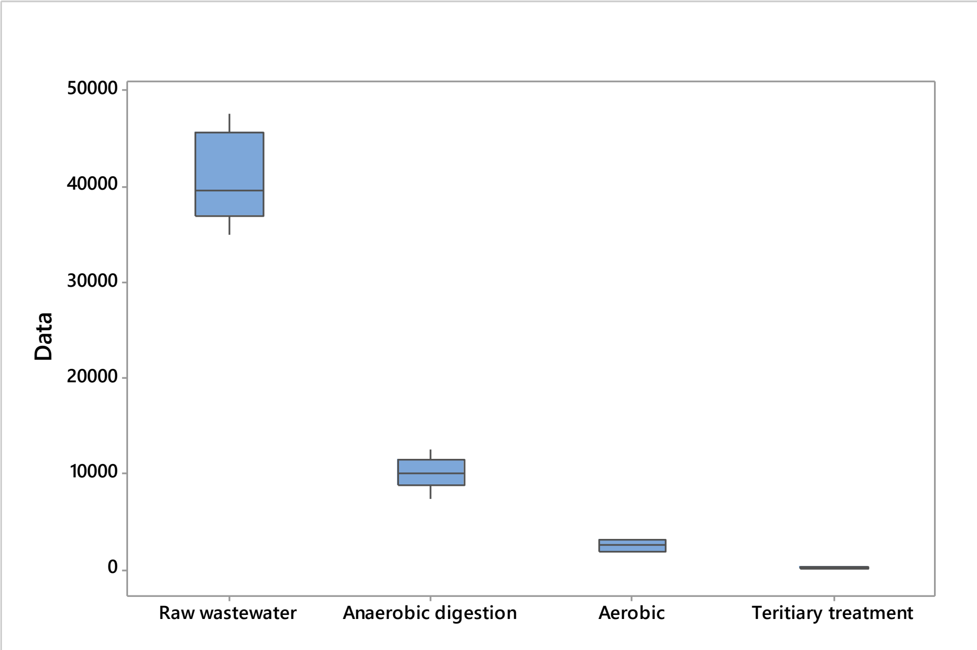

Figure 8: Boxplot of the data

Regression analysis gives the relationship between each of the predictors and dependent variable. R-square is used for validating the model. Regression analysis was carried out to find out the relationship between raw wastewater COD value and efficiency of the anaerobic reactor. Fig-9 depicts the fitted line plot for quadratic model for COD removal in anaerobic digester depending on raw wastewater characteristics. R-square was found to be 79.5%.

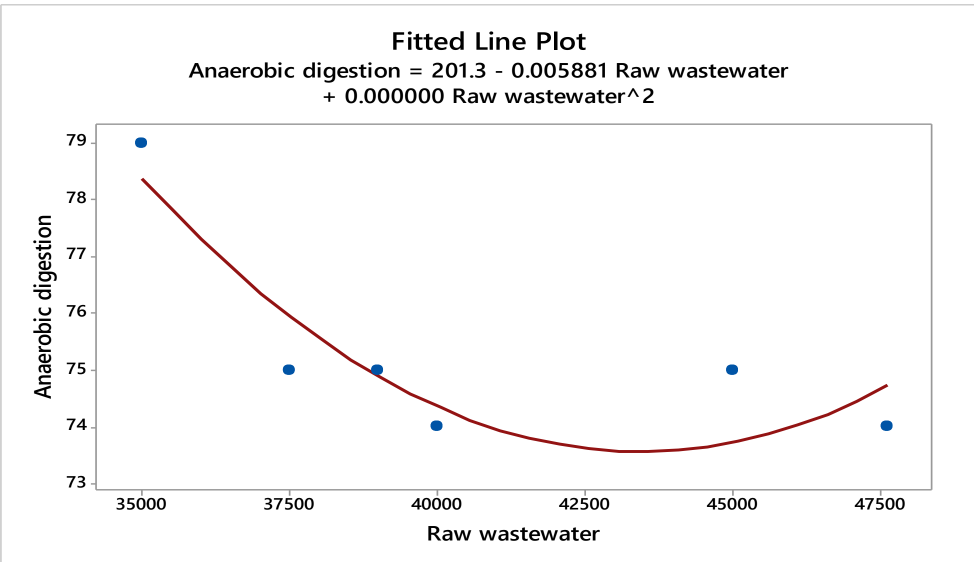

Figure 9: Fitted line plot

4. CONCLUSION

Performance analysis of a field scale wastewater treatment plant for marigold processing wastewater was carried out for one season for 6months. Field scale plant has shown good performance. COD removal efficiency was found to be satisfactory, where final outlet COD values were as per the CPCB norms. Anaerobic reactor has shown steady performance for all the months in that season, where VFA/Alkalinity ratios were also steady throughout the season. Statistical studies like box plot also have shown that the data represented each month was in good range. Regression plot fitted for quadratic model.

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CONFLICT OF INTEREST

There is no conflict of interest.

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